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A Planning Perspective

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B.C. HYDRO

THE SECOND KELLY LAKE TO CHEEKYE 500 KV TRANSMISSION LINE

A PLANNING PERSPECTIVE

SYSTEM PLANNING DIVISION
SYSTEM DEVELOPMENT

MARCH 1990

REPORT NO. SP 8903

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Executive Summary[1]

The purpose of this report is to outline B.C. Hydro's planning process for major transmission projects and to explain how that process led to more detailed studies for reinforcing the Interior to Lower Mainland electric transmission system. A primary component of those studies and the focus of this report is a second 500 kV single circuit transmission line between Kelly Lake Substation near Clinton and Cheekye Substation near Squamish. A schedule is included for meeting an in-service date as early as the fall of 1995. This date along with all other dates and project proposals in this report are best estimates based on information available as of the date of printing.

Approximately 70% of the electricity produced by B.C. Hydro is consumed in the Lower Mainland and on Vancouver Island. The transmission system serving these two regions is now operating at its maximum capacity and some station equipment will be installed to reinforce the system prior to 1995. Furthermore, approximately 75% of the forecast increase in electricity consumption over the next ten years is expected to occur in the Lower Mainland and on Vancouver Island and all planned generation developments are located at sites remote from these two regions.

By the mid 1990s, if growth trends continue and the Interior to Lower Mainland transmission system is not reinforced, loss of a major system element during times of high electricity consumption would result in the sudden reduction of generation output and interruption of electricity to customers and in an increased risk of a widespread blackout. Therefore, it is imperative that plans be made to reinforce the major transmission system bringing electricity to these regions in order to maintain system reliability.

B.C. Hydro is now planning the following reinforcements to the Interior to Lower Mainland transmission system by approximately the dates shown. The need for these projects will be dependent on continuing growth in electricity consumption.

1990 Complete the American Creek Series Capacitor Station north of Hope at which series capacitors are being installed at the mid-point of the two 500 kV transmission lines from Nicola Substation, near Merritt, to the Lower Mainland.

1993 Install a static var compensator in the Lower Mainland or on Vancouver Island.

1995 Construct a second 500 kV single circuit transmission line between Kelly Lake Substation and Cheekye Substation including series capacitors, possibly at the existing Creekside Series Capacitor Station near Pemberton.

1998 Construct a second 500 kV single circuit transmission line between Nicola Substation and Meridian Substation north of Coquitlam including series capacitors at the American Creek Series Capacitor Station.

2001 Install another static var compensator in the Lower Mainland or on Vancouver Island.

[1] There is a Glossary of Terms at the end of this report and many words and phrases in the main body of the report are referenced to the Glossary. In this Executive Summary and in the Introduction no such specific references are made.

The existing 500 kV transmission line between Kelly Lake and Cheekye is one of the most heavily used in the system. The planned second line would share electricity flow with the existing line and thereby maintain the present level of system reliability while supplying an increasing demand for electricity. In addition, transmission system losses would be greatly reduced. The total value of the savings in transmission losses that would be realized by constructing a second line could account for approximately 70% of the total capital and operating costs associated with the line.

The above proposed sequence of system reinforcements can respond to higher than expected growth in electricity consumption by installing additional short lead time static var compensators. The Kelly Lake to Cheekye line can be deferred if growth is lower than expected and if new generation north of Kelly Lake Substation and east of Nicola Substation is deferred.

The Kelly Lake to Cheekye project is now the subject of a comprehensive public consultation and route investigation process. This process, which includes environmental and engineering studies, is intended to define feasible routes for the proposed transmission line, to identify potential social and ecological impacts that could be caused by the construction and operation of the line and to determine ways of avoiding or mitigating those impacts. The results of these studies will determine under what conditions the project is environmentally and technically feasible. Once these conditions have been applied to the design and the routing, and the need for the project has been confirmed, B.C. Hydro will apply for an Energy Project Certificate to the Minister of Energy, Mines and Petroleum Resources requesting approval to construct the project.

1. Introduction

B.C. Hydro's mission is to support the economic growth of British Columbia through the efficient supply of electricity. As electricity consumption grows in the Lower Mainland and on Vancouver Island, it is imperative that the major transmission system bringing electricity to these regions be reinforced to maintain system reliability; that is, to maintain an assured supply of electricity.

This report outlines B.C. Hydro's planning process for major transmission projects and explains how that process led to more detailed studies for reinforcing the Interior to Lower Mainland Transmission System with a second 500 kV single circuit transmission line from Kelly Lake Substation near Clinton to Cheekye Substation near Squamish.

The following pages contain brief descriptions of:

* a typical electrical transmission system;

* B.C. Hydro's existing major transmission system;

* the forecast of electricity demand which is driving the need for transmission system reinforcement;

* the resource plan to meet the growing demand for electricity;

* the transmission planning process which determines what system reinforcements are needed; and,

* the planned second Kelly Lake to Cheekye 500 kV transmission line.

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2. Electrical Transmission Systems — What they are and how they are planned

Electric transmission systems are complex networks of transmission lines that deliver electricity from generating plants to places where the electricity is consumed. This section summarizes information not only on the transmission lines but also on the various stations in which the lines terminate and on the equipment located in those stations. More technical details can be found in the Glossary of Terms at the end of this report.

2.1 Elements of a Transmission System

Figure 1 is a schematic drawing of the basic elements of an electrical system from the generation plant to an individual customer. The transmission elements include the major transmission lines which transmit electricity directly from the generating plants to large central substations; the area transmission lines which take the electricity from the central substations to large industrial customers and to local area and distribution substations; and the distribution lines which deliver the electricity from the area and distribution substations to smaller industrial, commercial and residential customers.

Major transmission lines typically operate at the highest voltages[2] in the system while area transmission lines operate at intermediate voltages and distribution lines at the lowest voltages. B.C. Hydro's transmission system consists of over 17,000 km of lines operating at voltages from 500 kV[3] down to 69 kV.

The primary purpose of the major transmission system is to reliably[2] transmit electricity from remote generation resources to centres of high electricity consumption. This requires that the system voltages remain relatively constant during varying levels of electricity consumption, when lines and equipment are out of service and during sudden line outages.

Since the major generation resources in British Columbia are quite distant from where most of the electricity is consumed, high transmission voltages are required to economically transmit that electricity. The long distances and the large variability in consumption patterns also require that equipment be installed to control system voltages. Some of the key elements of the major transmission system are briefly described below.

Generators - The first component of any electrical system is the source of electricity; in this case, the generators at the hydroelectric dams. The water in the reservoirs flows through turbines which turn the generators, producing electricity. In addition to producing the electricity to drive motors and other electrical devices, generators also help control system voltage levels.

Transformers - Transformers are used to change transmission line voltages from one level to another. Generators produce electricity at low voltages. Transformers at the generating plants step-up this low voltage to a higher voltage (up to 500 kV in the B.C. Hydro system) for efficient transmission of electricity over long distances. Transformers are also used in substations (see below) to transform, or step down, the major transmission voltages to area transmission and distribution voltages.

[2] See Glossary.

[3] Kilovolt (kV) or thousand volts, the operating voltage of the line; see Glossary.

High Voltage Major Transmission Lines - The high voltage electricity from the generating stations is transmitted over the high voltage major transmission lines. These lines can transmit more electricity over longer distances than lower voltage lines and can do so with lower transmission losses.[4]

Substations - Substations interconnect transmission circuits and may include transformers for changing voltage levels. These stations also contain circuit breakers[4] and other equipment necessary to disconnect failed lines or transformers from the system.

Series Capacitors - Series capacitors[4] are inserted into transmission lines to increase the amount of electricity that can be transmitted and to help maintain acceptable system voltage levels.

Voltage Control Equipment - Static var compensators[4] (SVCs), synchronous condensers[4], shunt capacitors[4] and shunt reactors[4] are installed in substations to help control system voltage levels. During periods of low electricity consumption, system voltages tend to rise and operators switch in shunt reactors which lower system voltages to normal levels. As consumption increases and system voltages begin to drop below normal levels, the shunt reactors are switched out and shunt capacitors are switched in to raise voltage levels. Synchronous condensers and SVCs provide automatic continuous voltage control during sudden line outages.

2.2 Planning the Interior to Lower Mainland Transmission System

System transmission planning involves technical and economic studies to determine the best way to reinforce the system to accommodate increases in consumption and generation. The selection of options should be flexible enough to cover some of the uncertainties associated with such factors as the cost of money, changing growth rates and the range of alternatives in the resource plans. A significant part of the work of planning the Interior to Lower Mainland transmission system[4] is concerned with ensuring that proper system voltages can be maintained during normal and emergency conditions.

2.2.1 Technical Studies

An electric transmission system is technically complex and computer simulation studies must be conducted to predict its behaviour during specific conditions. The results of these studies are used both for operating the existing system and for determining future reinforcement requirements.

The studies provide information on such electrical system quantities as electric currents[4], voltages and transmission losses. These studies are used to ensure that equipment is not subjected to higher than its rated operating levels of current or voltage, that system voltages remain within acceptable limits and that voltage stability[4] is maintained following the loss of a critical system component such as a major transmission line.

The technical studies revealed that the primary factor limiting the transmission capability of the Interior to Lower Mainland transmission system is voltage stability.

[4] See Glossary.

2.2.2 Economic Studies

The economics of different transmission system reinforcement plans are analyzed using discounted cash flow[5] methods. Economic assessments compare options considering: capital costs, interest during construction, corporate overhead, depreciation charges over the expected useful lifetime of each component, expected annual operating and maintenance costs, taxes, cost of transmission losses, inflation and interest rates.

2.3 Planning for System Performance

In general, B.C. Hydro's major transmission system must continue to operate properly when a single element of the system fails (e.g., a transmission line). It must withstand this loss during times of peak demand[5] for electricity and other high stress conditions such as maximum output from any group of generating plants. During these conditions the system must have the following performance characteristics:

* no interruption of electricity to customers
* no loss of generation
* all equipment operating within design limits
* system voltages remain within acceptable limits

Transmission lines must be operated to maintain minimum safe conductor-to-ground clearances. As conductors heat up they get longer and conductor-to-ground clearances are reduced. Because electric current flow increases conductor temperature, transmission line capacity can be limited by ground clearance considerations during hot summer weather.

The system must maintain voltage stability during conditions such as periods of high electricity consumption. Voltage stability indicates the system is capable of withstanding a disturbance without voltages collapsing or dropping to extremely low levels. Voltage instability can result in widespread blackouts caused by cascading[5] tripouts[5] of transmission lines operating beyond their emergency limits.

As a member of the Western Systems Coordinating Council (WSCC)[5], B.C. Hydro must demonstrate that a disturbance within the B.C. Hydro system will not adversely affect the systems of neighbouring utilities.

[5] See Glossary.

3. The Existing Major Transmission System

Figure 2 is a schematic map of B.C. Hydro's existing major transmission system. The primary generation resources are in the north on the Peace River and in the southeast on the Columbia River system. Most electricity consumption is in the Lower Mainland and on Vancouver Island. As can be seen in Figure 2, most of the major transmission lines are routed from the hydroelectric generating plants in the north and southeast to the southwest corner of the province where most of the electricity is consumed. Electricity is supplied to the Lower Mainland and Vancouver Island from the Peace River through Kelly Lake Substation and from the Columbia River system through Nicola Substation.

The B.C. Hydro system is interconnected with the Bonneville Power Administration (BPA) system in the United States by two 500 kV transmission lines from Ingledow Substation in Surrey to BPA's Custer Substation south of Blaine, Washington, and by two 230 kV transmission lines in eastern B.C. These intertie lines provide for emergency support from BPA during disturbances in the B.C. Hydro system. They are also used throughout the year to export a firm supply[6] of electricity to Seattle City Light[7] and during periods of low domestic consumption the intertie lines can be used to export up to 2300 MW[6] of non-firm electricity. This export, as well as the electricity consumed in the Lower Mainland and on Vancouver Island, must flow through the Interior to Lower Mainland transmission system; as a consequence, that system is heavily used a large percentage of the time.

4. The Forecast of Future Electricity Demand

The most significant factor in determining when new generation and transmission facilities are needed is the forecast of future electricity demand. Figure 3 shows the 1989 forecast of future growth in peak electricity demand. This forecast was developed as a range of 'possible futures' based on such factors as expected population growth, future energy[6] prices and various economic development forecasts for the province.[8] The Probable forecast of approximately 2.7% average growth in peak demand per year for the next ten years is represented by the middle line in Figure 3. The Probable forecast is the 50th percentile. That is, there is a 50% chance the actual demand will be at or below the Probable forecast. There is a 95% chance the actual demand will be at or below the levels represented by the 95th percentile forecast.

The demand for electricity in individual areas of the province is expected to grow at rates different than the province as a whole and this must be considered when planning future transmission additions. For instance, the Lower Mainland and Vancouver Island regions now have a total peak demand of about 5400 MW (approximately 70% of the system total) and these regions are expected to account for approximately 75% of the total probable forecast growth in demand over the next ten years with very little change expected in that relative amount over the next twenty years. This means there is a 50% chance the total demand for electricity in the Lower Mainland and Vancouver Island regions will exceed 7000 MW by about the end of the century.

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[6] See Glossary.

[7] The contract with Seattle City Light (SCL) is for a guaranteed supply of electric power which ranges from 150 MW in the summer up to 300 MW in the winter (B.C. Hydro's peak period). This came about when SCL agreed not to raise their Ross Dam and flood part of the Skagit Valley in British Columbia.

[8] Historically, there has been a close correlation between growth of Gross Provincial Domestic Product and growth in electrical demand. While there is no reason to believe that this historical relationship will continue indefinitely, there is also no reason to expect a marked deviation over the forecast period.

5. The Resource Plan

As electricity consumption grows, resources must be developed to supply the increase. Each year a resource plan is proposed based on the latest forecast of future electricity demand.

Following are brief summaries of the new resources now being considered to provide electricity for use by B.C. Hydro's customers. There are sufficient resources listed to meet the Probable forecast shown in Figure 3. Some developments can be advanced or delayed if actual growth is above or below the Probable. More information on resource options can be found in the latest resource plan report.

Power Smart Programs – These are on-going, customer- oriented, energy conservation programs which reduce future growth of consumption by encouraging more efficient use of electricity. This benefits both the customer (through lower electricity bills) and B.C. Hydro (by postponing the need for new facilities, thus lowering financial commitments and delaying environmental impacts).

Resource Smart Initiatives – These on-going programs and projects are intended to make existing generation and system facilities more efficient in order to obtain significant additional energy from the B.C. Hydro system and allow development of new facilities to be postponed. Some of the proposed Resource Smart projects are listed under Lower Columbia Development, below.

Independent Power Producers – Independent power production is defined as electricity generation by a privately owned facility which can be connected to the B.C. Hydro system for the purpose of selling electricity. The Independent Power Producer program will provide resource options which will help B.C. Hydro meet its customer requirements while contributing to the province's economic development.

Coordination & Purchases

A number of possible coordination and purchase agreements with neighbouring utilities and a large industrial firm offer a potentially attractive combination of flexibility and fairly-priced energy to B.C. Hydro.

TransAlta

B.C. Hydro, which operates a system that relies predominately on hydroelectric generation, is negotiating for the purchase of electricity and coordination of generation resources with TransAlta in Alberta, which operates a system that relies predominately on thermal generation. These negotiations are now in their early stages but agreements are anticipated which would utilize the different characteristics of the two systems to the mutual benefit of customers in British Columbia and Alberta.

Bonneville Power Administration

Coordination with Bonneville Power Administration (BPA), which operates a large electrical system in the northwest part of the United States, would make it possible for B.C. Hydro to more effectively manage reservoir storage on the Peace and Columbia rivers. Current negotiations are focused on reaching a limited coordination agreement for the operation of Canadian and American reservoirs on the Columbia River this year. B.C. Hydro and BPA have agreed to study other alternatives for future coordination when the first agreement is in place.

Alcan Purchase

Alcan is proceeding with construction of its Kemano Completion Project southeast of Kitimat for service by 1995, ahead of Alcan's requirements for industrial purposes. Detailed negotiations for the purchase by B.C. Hydro of electricity that will be generated by the Kemano Completion Project and for coordination of reservoir operations have been completed and a final agreement on purchases and coordination was signed on 27 February 1990.

Downstream Benefits Arising from the Columbia River Treaty – The Canadian entitlement to downstream benefits resulting from the operation of water storage in the reservoirs at the existing Duncan, Keenleyside and Mica dams under the Columbia River Treaty was sold to the United States for a period of 30 years from the commencement of operation of each project. Those downstream benefits will revert to British Columbia gradually, starting in 1998/99.

Lower Columbia Development – The Lower Columbia Development consists of seven potential hydroelectric facilities located in the general area of Trail and Castlegar in the southeastern part of the province: Keenleyside power plant project, Waneta power plant expansion, addition of a fourth generating unit at Seven Mile power plant, Brilliant power plant expansion, Duncan power plant project, Border project and Murphy Creek project. All of these but the Border and Murphy Creek projects are Resource Smart initiatives. All seven of these are being considered because of their relatively low environmental impact and because they constitute the final stage of the 'two river policy' that was initiated by the Province in the early 1960s.

Peace Site C – Site C, near Fort St. John, would be the third dam on the Peace River (W.A.C. Bennett and Peace Canyon dams near Hudson's Hope are already producing electricity). Should public consumption of electricity continue to grow at the current forecast rate, electricity from Site C could be required by approximately the turn of the century.

Additional Resources Beyond 2000 – Selection of other resource additions to the system has not been made. The choices will be affected by actual growth and forecasts of growth over the next few years and by the effectiveness of the programs described above.

As can be seen from this list, resource options other than the development of large generating facilities are taking precedence in the preparation of the Resource Plan. Still, virtually all these resources are located quite far from where most of the electricity is consumed. Therefore, there is a continuing need to reinforce the major transmission system to reliably deliver electricity from the new resources to the growing customer requirements.

6. Planning Major Transmission into the Lower Mainland

The primary planning and design requirements for the transmission system from Kelly Lake and Nicola substations into the Lower Mainland are determined by electricity consumption in the Lower Mainland and on Vancouver Island and by the location and size of the generation resources serving those regions. Over the next ten years, domestic consumption in the Lower Mainland and on Vancouver Island is expected to grow by almost 1900 MW. Almost 350 MW of that growth is expected to be conserved by Power Smart Programs leaving more than 1550 MW to be supplied through the Interior to Lower Mainland transmission system from remote generation sources. For this system it is voltage stability which most significantly limits the amount of electricity that can be transmitted. That is, the system voltage levels must remain within acceptable limits following a severe disturbance. Voltage instability can lead to the electrical break-up of the system and blackouts. The Interior to Lower Mainland system will require reinforcing to reliably deliver the additional electricity to serve the increasing levels of consumption in the south west portion of the province.

6.1 Existing System Restrictions

The Interior to Lower Mainland transmission system now has essentially no spare capacity. There are two significant restrictions on this system. One is a conductor-to-ground clearance restriction in the older 500 kV transmission lines and the other is voltage stability.

Conductor-to-Ground Clearance Restrictions - Recent surveys of the existing Peace 500 kV transmission lines revealed that clearances between the electrical conductors and the ground severely limit output of the Peace River generators during hot summer weather. The Peace transmission system is not adequate for expected future growth in electricity demand and generating plant additions. Uprating the Peace transmission lines, including the existing Kelly Lake to Cheekye 500 kV line, is presently under way and should be completed by the fall of 1991.

Voltage Stability Restrictions - During the next ten years the Interior to Lower Mainland transmission system will be limited by voltage stability considerations. Two high stress system conditions are studied when evaluating different plans for the reinforcement of this system during this time period:

1. Peak demand for electricity with the generation resources in the north (on the Peace River and Alcan's Kemano generation) operating at their maximum capacities; and,

2. Peak demand for electricity with the generation resources in the southeast (on the Columbia River system) operating at their maximum capacities.

6.2 Reinforcement Options

Near term solutions to the voltage stability problem are being provided by conversion of some of the generators at the Burrard Thermal Generating Plant near Port Moody to synchronous condenser operation and by the construction of the American Creek Series Capacitor Station north of Hope.

Burrard Thermal Synchronous Condensers – To help maintain voltage levels in the Lower Mainland following the loss of a major transmission line, four of the six generators at the Burrard Thermal plant have been converted to synchronous condenser operation. The remaining two units cannot be converted because they are required for back-up generating capacity. However, those two units will be placed on-line during times of peak demand for electricity for the next few years to provide needed additional voltage control.

American Creek Series Capacitor Station – The addition of series capacitors in the two Nicola to Lower Mainland 500 kV transmission lines in 1990 will help maintain acceptable voltage levels in the Lower Mainland and on Vancouver Island and will increase the transmission capacity of the system.

The system, with the reinforcements described above, will provide adequate transmission capacity until the peak domestic demand for electricity in the Lower Mainland and on Vancouver Island reaches a combined total of about 6030 MW, approximately 650 MW above present peak demand. Additional system reinforcement will be required at that time which is now expected to occur by about the year 1993.

Many options have been studied for reinforcing the Interior to Lower Mainland transmission system to increase its transmission capacity and to improve voltage stability. Voltage regulation devices, series capacitors and new transmission lines have all been considered in various combinations. The specific system reinforcement options considered beyond 1990 are listed below. Each of these additions would improve voltage stability and increase the transmission capacity of the system.

1. **Static Var Compensators:** Static var compensators (SVCs) can be installed in substations to help control voltage levels and prevent voltage collapse following sudden outages of transmission lines. The first SVC installation is now scheduled for 1993.

2. **Series Capacitors:** The option of using only series capacitors to reinforce the transmission system was considered. This option consisted of increasing the amount of series compensation of the existing four Interior to Lower Mainland 500 kV transmission lines (two each from Kelly Lake and Nicola substations) and adding series compensation to the 500 kV transmission line between Nicola and Kelly Lake, which is presently uncompensated. Installing more series compensation in the Interior to Lower Mainland transmission system would require significant changes to protective relaying equipment.[9] Also, the cost of series capacitors increases dramatically as the level of compensation increases. Providing more series compensation in these lines would be very expensive, making this option uneconomic when compared to other alternatives.

3. **Additional Transmission Lines:** Adding more transmission lines in parallel with existing transmission lines is an obvious way to increase the transmission system capability. Additional lines would improve voltage stability and increase the transmission capacity of the system. In addition, transmission losses would be substantially reduced. Several options for transmission line additions have been studied:

[9] See Glossary.

a. **Kelly Lake to Cheekye 500 kV Transmission Line** – The option of building a second 500 kV transmission line between Kelly Lake and Cheekye substations includes the installation of a series capacitor bank near the mid-point of the line, possibly at the existing Creekside Series Capacitor Station near Pemberton, depending on routing. This line would be the shortest and least costly of the alternative transmission lines into the Lower Mainland and would provide a significant increase in transmission system capability. It would also significantly reduce transmission losses. The existing 500 kV line between Kelly Lake and Cheekye is one of the most heavily used lines in the system because much of Vancouver Island's electricity flows over that line in addition to the electricity required in the Lower Mainland. The proposed second Kelly Lake to Cheekye 500 kV line would improve the reliability of supply to both the Lower Mainland and Vancouver Island.

b. **Kelly Lake to Ingledow 500 kV Transmission Line** – The route assumed for this transmission line basically follows the existing Kelly Lake to Ingledow 500 kV transmission line through the Fraser Canyon. This option would include the installation of series capacitors at or near the existing Chapmans Series Capacitor Station. Although this line would also provide a large increase in transmission system capability, it would be significantly longer and more costly than the proposed Kelly Lake to Cheekye line and less effective at reducing transmission losses. The lead time necessary to build this line is estimated to be at least three years longer than for the Kelly Lake to Cheekye line.

c. **Nicola to Meridian 500 kV Transmission Line** – It is assumed that this line would be built adjacent to the existing 500 kV line connecting Nicola and Meridian substations. It would include the provision of series capacitors at or near the American Creek Series Capacitor Station which will be completed this year. This line also would provide a substantial increase in transmission system capacity and would reduce transmission losses but it would be significantly longer and more costly than the Kelly Lake to Cheekye line. The second Nicola to Meridian 500 kV transmission line is included in the preliminary plans for the reinforcement of the eastern side of the Interior to Lower Mainland transmission system with a possible in-service date in the late 1990s.

6.3 Recommendations and Rationale

Based on the latest forecast of future electricity demand, the resource plan and transmission planning studies, the Interior to Lower Mainland transmission system will require additional reinforcement beginning in 1993. If electricity consumption continues to grow and the system is not reinforced, loss of a major transmission line during periods of high electricity consumption would result in the quick disconnection (usually automatic) of one or more generating units and the interruption of electricity to customers and an increased risk of a widespread blackout or extremely low voltages in large areas of the Lower Mainland, Northern Washington and Vancouver Island. If there can be electricity interruptions to customers in Washington because of this type of disturbance in the B.C. Hydro system, it would be a violation of the WSCC planning criteria.

The following system additions are being considered for installation starting in about 1993, possibly by the dates shown:

* 1993 Installation of a static var compensator in the Lower Mainland or on Vancouver Island;

* 1995 Construction of a second 500 kV transmission line between Kelly Lake and Cheekye substations including a series capacitor bank near the mid-point of the line, possibly at the existing station at Creekside, depending on the route selected;

* 1998 Construction of a second 500 kV transmission line between Nicola Substation near Merritt and Meridian Substation north of Coquitlam including a series capacitor bank near the mid-point of the line, presumably at the existing American Creek Capacitor Station north of Hope; and

* 2001 Installation of another static var compensator in the Lower Mainland or on Vancouver Island.

Since B.C. Hydro has no operating experience with SVCs, the above recommendations do not rely heavily on SVCs in the early years. The initial SVC installation proposed for 1993 would provide design and operating experience with these devices.

The planned second Kelly Lake to Cheekye transmission line would provide a proven means of reinforcing the system. The existing Kelly Lake to Cheekye line is one of the most heavily used 500 kV lines in the major transmission system. The new line would maintain system reliability and greatly reduce system losses which would cover, over its operating lifetime, approximately 70% of the total capital and operating costs associated with the line, based on forecast energy costs and growth in electricity demand.

The above recommendations can be rescheduled to respond to higher than expected rates of growth or the development of firm export opportunities by advancing the short lead-time SVC projects. Advancing the second Kelly Lake to Cheekye 500 kV line earlier than 1995 does not appear to be possible. Since the next resource addition is scheduled to be Alcan's Kemano Completion Project in early 1995, it is appropriate to first reinforce the western side of the Interior to Lower Mainland transmission system by adding a second Kelly Lake to Cheekye line followed later by reinforcing the eastern side of the system with a second Nicola to Meridian line. Lower growth rates would result in the postponing and possible relative rescheduling of these projects.

7. The Second Kelly Lake to Cheekye 500 KV Transmission Line

7.1 Background

During the last half of the 1970s, the forecasts of electricity demand indicated that some new system additions would soon be required to bring more electricity into the Lower Mainland to serve the growing demand there and on Vancouver Island. By going through a study process similar to what has been outlined in this report, a decision was made then that a second Kelly Lake to Cheekye 500 kV transmission line was the best choice to meet that requirement. The line was initially scheduled to be completed in 1986. However, because of the high long-range forecast at that time, the plan was changed to a double circuit 500 kV line with a 1987 in-service date. That is, the supporting towers would be constructed so they could support the conductors for two 500 kV circuits rather than just one.

By 1980, however, there were indications that the rate of growth was slowing and the project was rescheduled to 1988, then to 1989. In 1982 it was again rescheduled for completion in 1990 as a single circuit line. The long range forecast had dropped enough by 1983 that plans for the line were postponed indefinitely.

Within the last two years an increasing forecast of electricity demand has resulted in a comprehensive review of the system plan aimed at determining what additions would be needed within the next ten to twenty years to meet the increase. The system additions and improvements discussed in Section 6 are buying time before the next transmission line must be built into the Lower Mainland but options and time appear to be running out. As a consequence, a second 500 kV transmission line between Kelly Lake and Cheekye substations is once again being considered.

7.2 Project Description

The new line would consist of a single circuit, 500 kV, steel tower transmission line between Kelly Lake and Cheekye substations. The line would be approximately 200 km long, depending on the route selected. Both self- supporting and guyed structures would be used in the construction of the second 500 kV line with the requirements of terrain, climate and span length determining which type of structure is appropriate in each location. However, the choice of tower types has not yet been determined. Schematic drawings of the types of structures being considered are shown in Figure 4. The structures shown in Figure 4a are similar to those of the existing 500 kV line between Kelly Lake and Cheekye. Those shown in Figure 4b would allow a reduced right-of-way width requirement and correspondingly less clearing as well as some potential electrical benefits but are taller and would tend to be more visible. It is possible that both types of structures could be used with the choice along each section of the line depending on local factors.

When this project was planned a few years ago, one of the options was for double-circuit construction. Because the forecast is now relatively low, there appears to be no need for a third 500 kV line between Kelly Lake and Cheekye within the foreseeable future and it would not be economic to build a double circuit line at this time.

In the early 1980s, plans were announced for a new substation, called Creekside, to be constructed north of Mount Currie. There are now no plans for a new substation between Kelly Lake and Cheekye. However, to enable the new line to transmit the maximum amount of electricity, series capacitors would be inserted near the mid-point of the line, possibly at the existing Creekside Capacitor Station northeast of Pemberton, depending on the selected route.

A route for the new line has not been selected. When this project was first considered, the plan was to route the new line parallel and adjacent to the existing 500 kV line from Kelly Lake Substation to the Bridge River area. From there, the intention was to remove one of the existing 230 kV lines, which was built in the 1940s, and utilize that right-of-way for the new 500 kV line from Bridge River to Cheekye Substation. Comprehensive route studies were carried out at that time which identified areas where deviations from the right-of-way of the 230 kV line offered some land use or other social and environmental advantages. In particular, deviations were recommended from south of Anderson Lake to past Gates Lake, in the Pemberton and Whistler areas and in the Cheakamus Canyon. However, before those options could adequately be reviewed with the public the project was postponed.

7.3 Project Studies and Schedule

New route studies are now in progress which are using relevant information from the previous studies but are not limited to those findings. More environmental assessment studies are being carried out to identify feasible route options and potential ecological and social impacts of the new line and to determine ways of avoiding or mitigating those impacts. Figure 5 shows some of the possible routes being considered. The environmental studies are being closely coordinated with engineering studies which address line security and cost. Public consultation is an integral part of the process.

A project schedule which would meet an in-service date as early as the fall of 1995 is outlined in Figures 6 and 7. Figure 6 covers activities during Phase 1, the planning and development phase, and Figure 7 covers activities during Phase 2, the design and construction phase. Although public consultation is an on-going activity that will continue throughout both phases, particular emphasis is being placed on public involvement during Phase 1, as identified in the schedule.

The results of these activities will determine whether the project is environmentally and technically feasible. If it is, and if growth trends continue to demonstrate a need for system reinforcement, then B.C. Hydro will apply for an Energy Project Certificate to the Minister of Energy, Mines and Petroleum Resources requesting approval to construct the project.

Glossary of Terms

Alternating Current (AC) is electric current which alternates its direction of flow periodically. The electricity supplied to homes in North America alternates at a frequency of 60 cycles per second or Hertz (Hz).

Ampere (A) or Amp is a unit for measuring electric current flow. The current that flows in a typical 60 watt household light bulb is about one-half ampere. Very high currents are measured in kiloamperes or kiloamps (abbreviated as kA). One kiloamp is equal to one thousand amps.

Capacitors are connected together in series and parallel to form the large capacitor banks used in electrical transmission systems. Capacitor banks are connected in series with transmission lines to reduce transmission system impedance (see below). They are also connected in 'shunt' (i.e., between a live conductor and the ground or between live conductors) to help raise system voltages.

Cascading (see Tripout) refers to multiple tripouts of generators and transmission system equipment caused by the loss of one or more elements which results in the automatic tripping out of other equipment which would otherwise have to operate beyond its emergency limits and that, in turn, can cause further tripouts.

Circuit Breakers are fast switches used to interrupt electric current flow. The high voltage circuit breakers used in major transmission system substations are capable of interrupting electric current of tens of thousands of amperes.

Current (see Alternating Current and Ampere) is the flow of electrons in electrical equipment such as transmission lines. Electric current is measured in units called amperes.

Demand (see Electricity Demand and Peak Demand)

Discounted Cash Flow is a method of economic analysis which takes proper account of interest and inflation rates when determining the total value of a series of expenditures and earnings over a period of time.

Electric Energy (see Watt Hour) is the amount of electricity produced, transmitted or consumed in a given period of time. A 100 watt light bulb consumes 100 watt hours of electricity for each hour it is turned on.

Electricity Demand is the amount of electricity (usually measured in megawatts –see Watt) being consumed at any time by customers connected to an electrical transmission system.

Energy (see Electric Energy)

Firm Supply is the level of supply of electricity a customer can count on during periods of peak demand for electricity with one system element out of service.

Impedance is the property of a conductor or circuit which resists, or impedes, the flow of an electric current.

Interior to Lower Mainland Transmission System can be defined as those major transmission lines feeding into the large Lower Mainland substations (Cheekye near Squamish, Meridian north of Coquitlam and Ingledow in Surrey) from Kelly Lake Substation near Clinton and Nicola Substation near Merritt. It also includes the 500 kV transmission line between Kelly Lake and Nicola.

kV is the abbreviation for kilovolt (see Volt).

Losses (see Transmission Losses)

MW is the abbreviation for megawatt (see Watt).

Peak Demand (see Electricity Demand) is the highest level of electricity consumption experienced by an electrical system in a given period of time (e.g., day, month, season or year).

Protective Relaying Equipment detects faults in the system and initiates the disconnection of the faulty devices to minimize the damage to those devices and to protect other devices from damage.

Reactors are made up of a ferrous (i.e., magnetic) core wound with many turns of copper wire. Reactors come in a large range of sizes and types. Very large reactors are used in large electrical systems. They are connected in series with distribution lines to limit short circuit current levels. They are also connected in 'shunt' (i.e., between a live conductor and the ground or between live conductors) to help lower system voltages during periods of low electricity consumption.

Reliability is a measure of the continuity of electric service over a long period of time.

Series Capacitors (see Capacitors)

Shunt Capacitors (see Capacitors)

Shunt Reactors (see Reactors)

Static var compensators (SVCs) are devices which are used to control transmission system voltages. An SVC is made up of capacitors, reactors and solid state switches called thyristors. The very quick response of the thyristors permits an SVC to quickly react to, and compensate for, events which cause changes in system voltage. The thyristors also permit the output of the SVC to be continuously varied throughout its range rather then adjusted in large blocks as is the case for banks of shunt capacitors or reactors which are switched in and out using circuit breakers.

Synchronous Condensers are rotating machines which serve the same purpose as static var compensators by providing fast control of system voltages to improve system voltage stability. This fast voltage control together with their rotational inertia also aids system transient and dynamic stability.

Transmission Losses are energy losses in electrical systems which result from the heating caused by the flow of electric current through the conductors.

Tripout (see Cascading) is the disconnection of an electrical system element (e.g., transmission line, transformer, generator, etc.) by the action of circuit breakers usually initiated automatically by protective relaying equipment.

Volt (V) is the unit for measuring voltage (see below). Very high voltages are measured in kilovolts (abbreviated as kV). One kilovolt is equal to one thousand volts.

Voltage (see Volt) is the electric 'force', measured in volts, which causes current, measured in amperes (see above), to flow in electrical circuits.

Voltage Stability is the ability of the electrical transmission system to withstand the failure of a system element such as a transmission line or transformer; an unstable system can result in voltage collapse at the receiving end of the system which can lead to either widespread blackouts or large areas of very low voltages. Very low voltages can damage equipment, such as motors, due to overheating caused by the resulting high electric current flow.

Watt (W) is the unit for measuring the rate of generating, transmitting or consuming electricity. High rates of consumption are measured in kilowatts (abbreviated as kW), megawatts (MW), and gigawatts (GW). One kilowatt is equal to one thousand watts, one megawatt is equal to one thousand kilowatts and one gigawatt is equal to one thousand megawatts.

Watt Hour (W.h) is the unit of measure for electrical energy or work. A 100 watt light bulb operating continuously for ten hours will consume one thousand watt hours (or one kilowatt hour, kW.h) of electricity. A gigawatt hour is one million kilowatt hours.

WSCC -The Western Systems Coordinating Council is an organization of over 60 electric utilities in two western provinces of Canada, 14 western states of the United States and the northern portion of Baja California, Mexico. The WSCC provides a forum for the coordination of the planning, design and operation activities of its member utilities. The WSCC is one of nine regional councils which comprise the North American Electric Reliability Council (NERC). The function of NERC is to coordinate, promote and communicate reliability matters for North America's electric utilities.

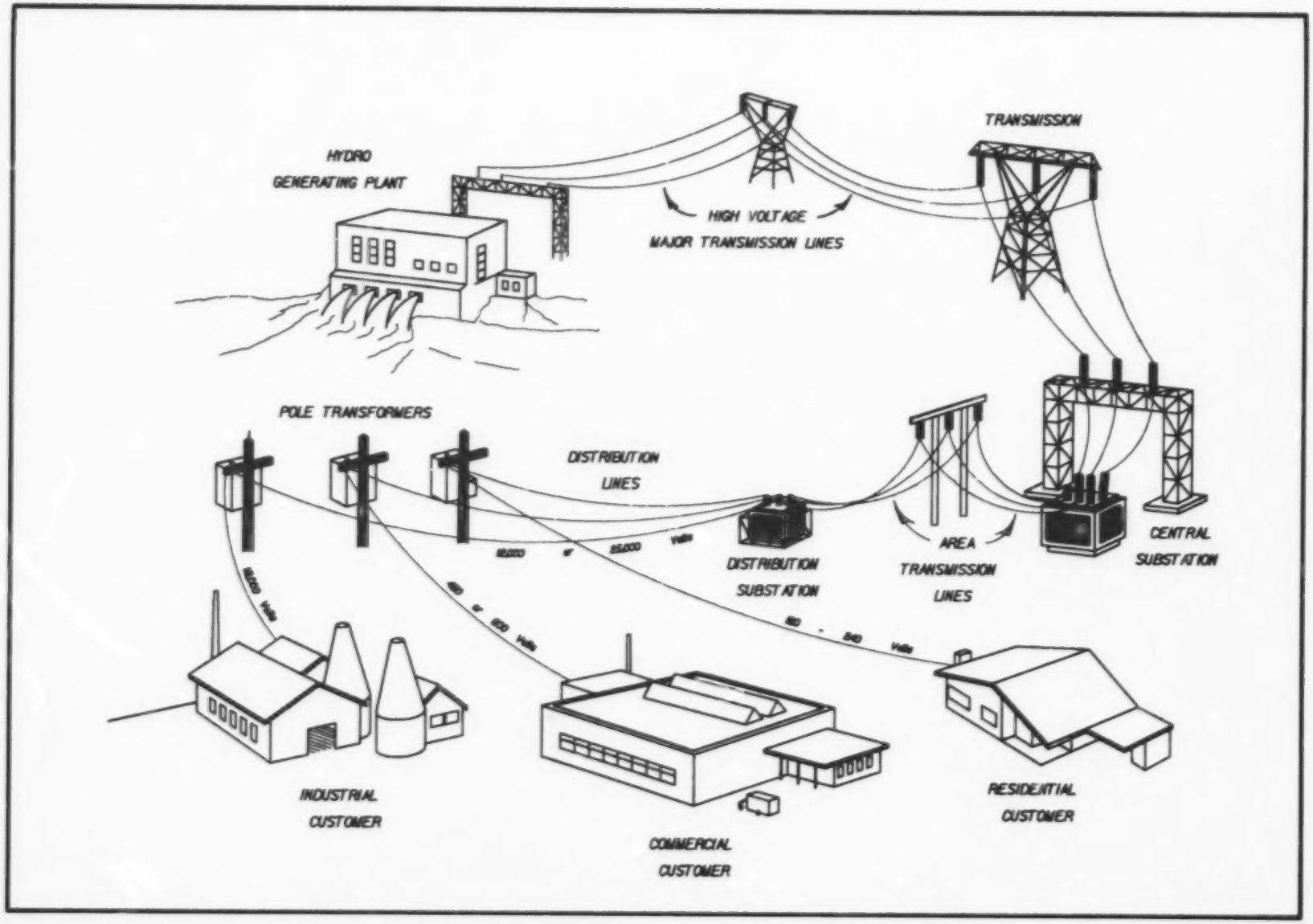


FIGURE 1 - BASIC ELEMENTS OF AN ELECTRICAL SYSTEM

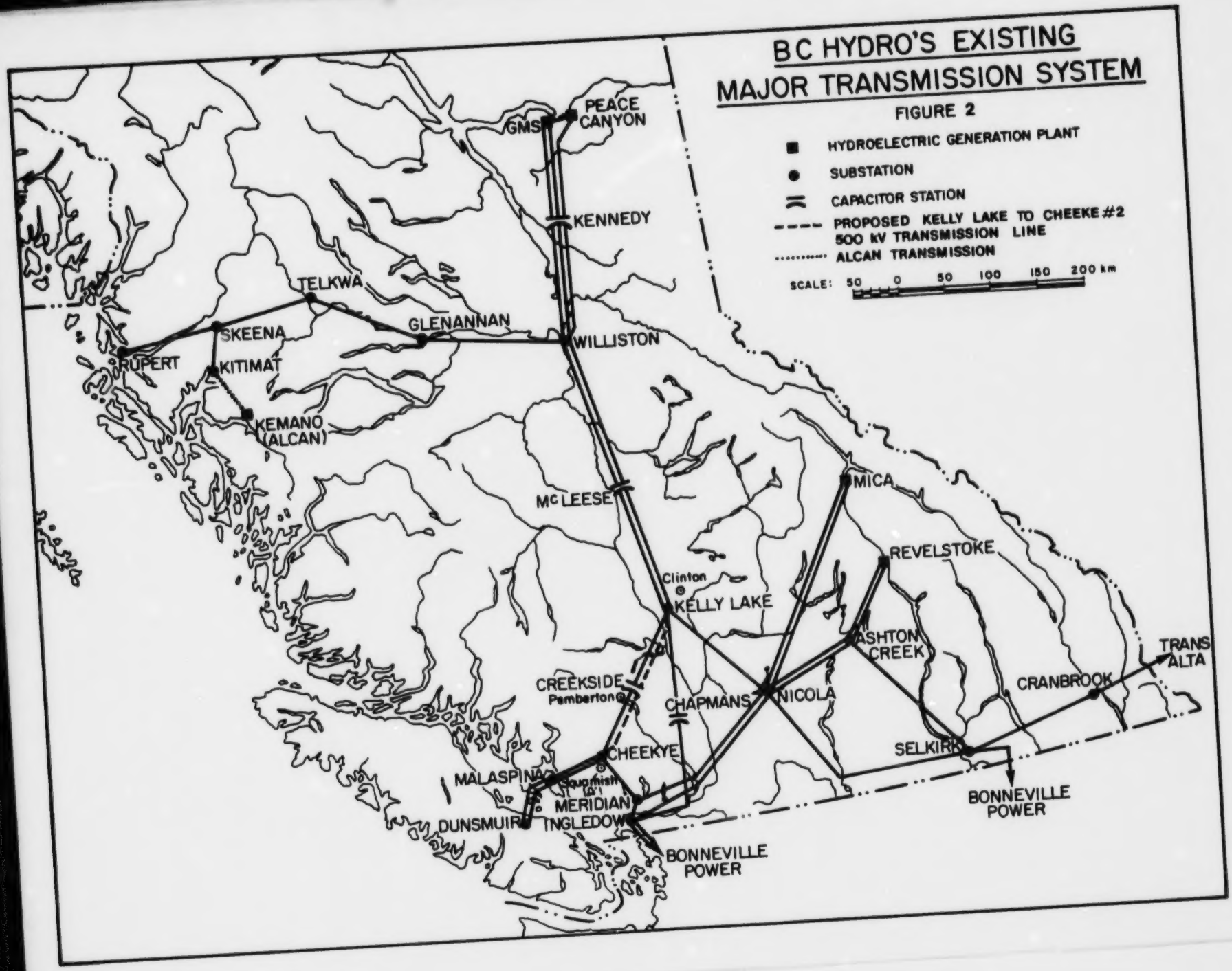
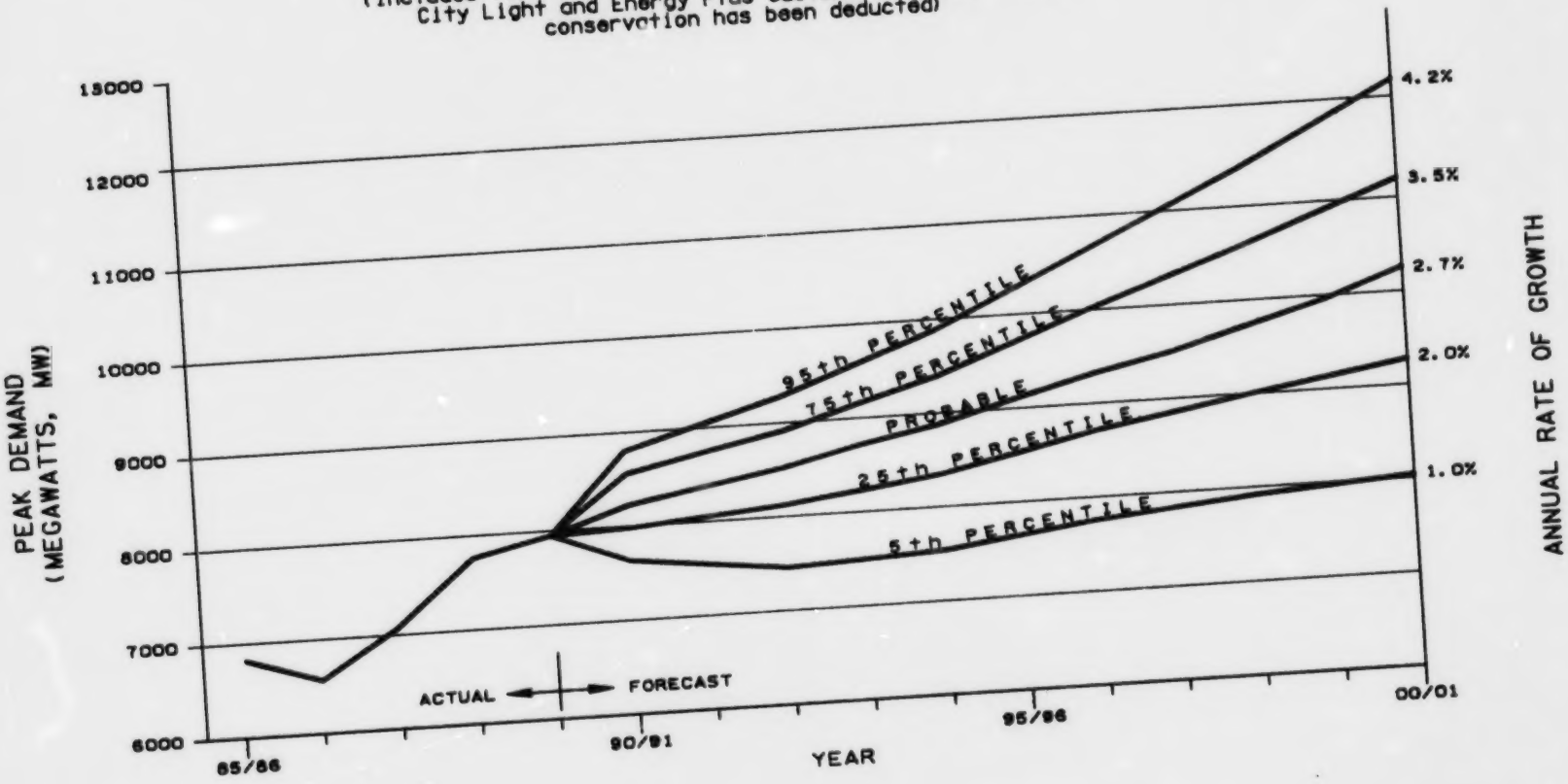

BC HYDRO'S EXISTING
MAJOR TRANSMISSION SYSTEM
FIGURE 2
HYDROELECTRIC GENERATION PLANT
SUBSTATION
CAPACITOR STATION
PROPOSED KELLY LAKE TO CHEEKE #2
500 kV TRANSMISSION LINE
ALCAN TRANSMISSION
SCALE: 50 0 50 100 150 200 km
PEACE CANYON
GMS
KENNEDY
TELKWA
GLENANNAN
SKEENA
WILLISTON
PRINCE RUPERT
KITIMAT
KEMANO (ALCAN)
McLEESE
MICA
REVELSTOKE
Clinton
KELLY LAKE
ASHTON CREEK
TRANS ALTA
CRANBROOK
CREEKSIDE
Pemberton
CHAPMANS
NICOLA
SELKIRK
CHEEKYE
MALASPINA
Squamish
MERIDIAN
INGLEDOW
DUNSMUIR
BONNEVILLE POWER
BONNEVILLE POWER

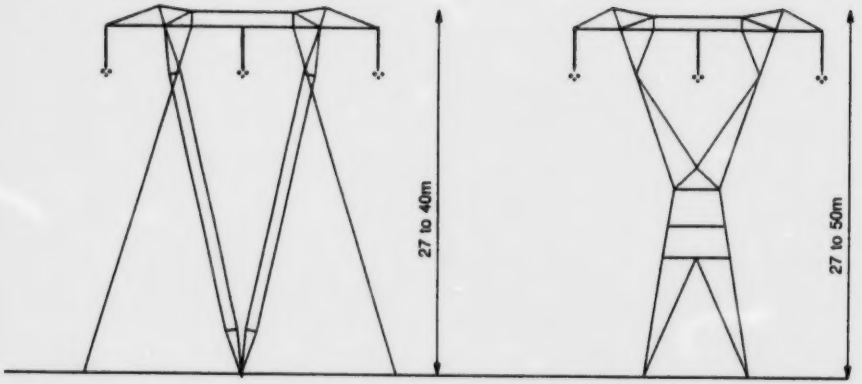
FIGURE 3

1989 B.C. HYDRO FORECAST OF PEAK ELECTRICITY DEMAND

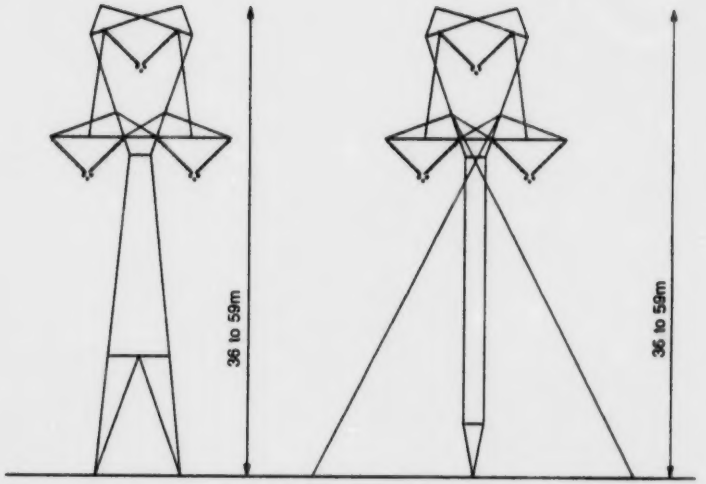
(Includes firm commitments to West Kootenay Power, Seattle City Light and Energy Plus customers; Power Smart conservation has been deducted)



Basic Structure Types
Kelly Lake - Cheekye
500 kV Transmission Project



(a)



(b)

Figure 4

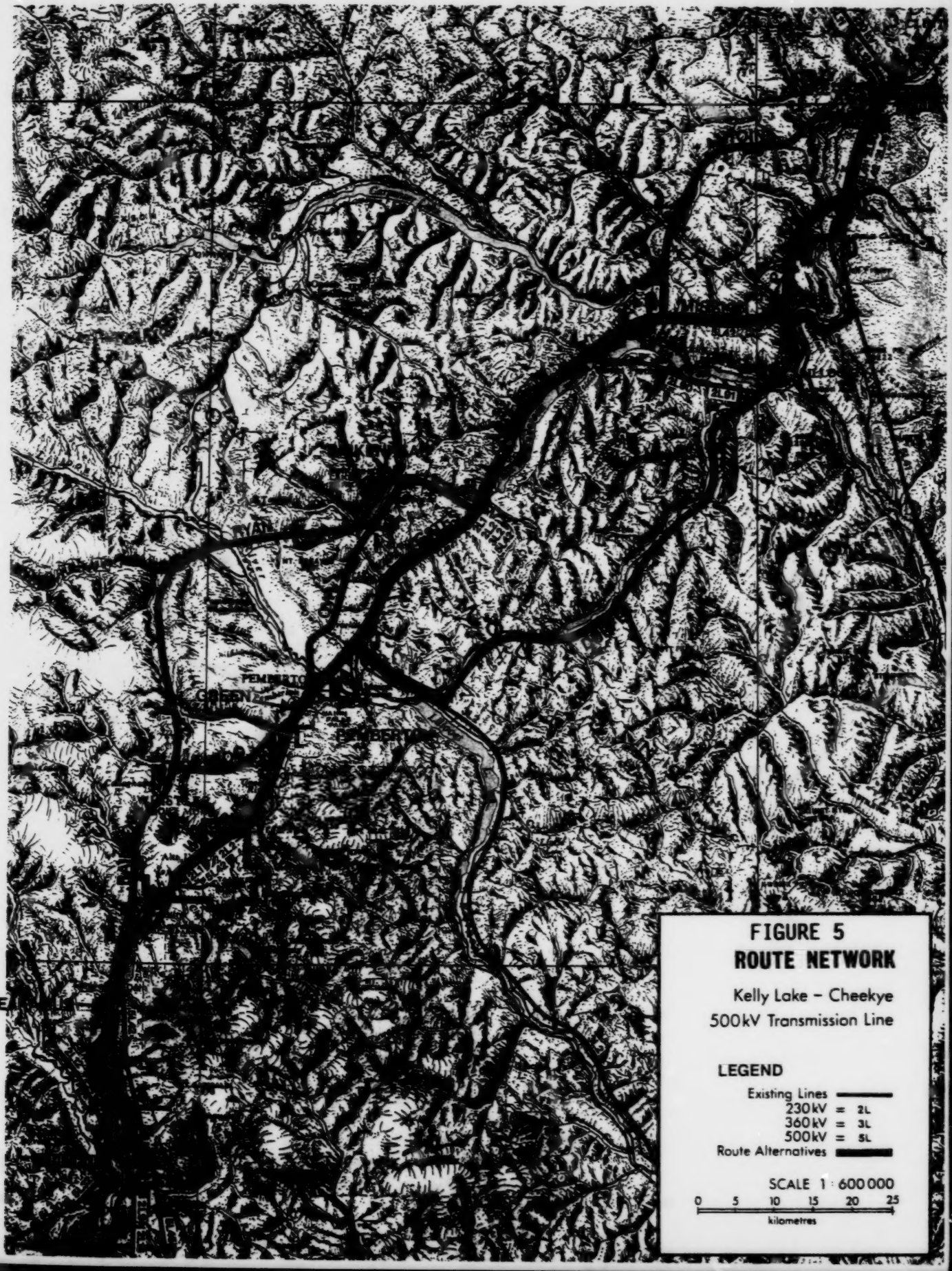


FIGURE 5
ROUTE NETWORK

Kelly Lake – Cheekye
500kV Transmission Line

LEGEND

Existing Lines
230kV = 2L
360kV = 3L
500kV = 5L
Route Alternatives

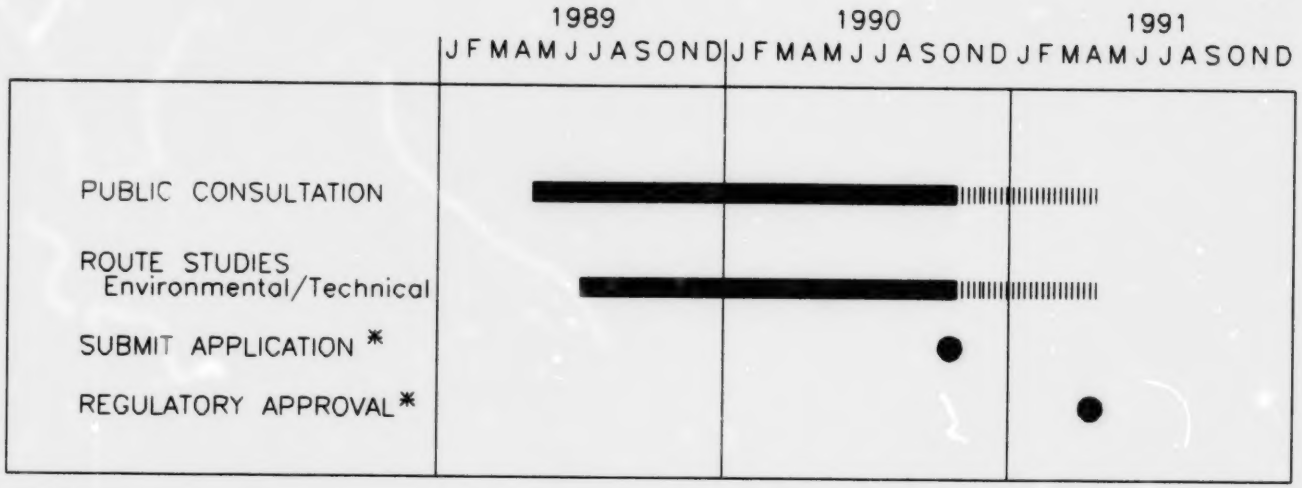
SCALE 1 : 600 000

0 5 10 15 20 25
kilometres

FIGURE 6

KELLY LAKE – CHEEKYE
500 kV TRANSMISSION LINE PROJECT
PROPOSED PROJECT SCHEDULE

PHASE 1
PLANNING AND DEVELOPMENT


1989
1990
1991
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
PUBLIC CONSULTATION
ROUTE STUDIES
Environmental/Technical
SUBMIT APPLICATION *
REGULATORY APPROVAL *

* The Project Prospectus dated September 1989 indicated an April 1990 date for submission of an Energy Project Cerificate (EPC) application with expected regulatory approval about 6 months later. However some of the Phase 1 activities have taken longer than foreseen. Therefore the earliest anticipated date for submission of an EPC application is now October 1990, with expected regulatory approval in April 1991.

FIGURE 7

KELLY LAKE – CHEEKYE
500 kV TRANSMISSION LINE PROJECT
PROPOSED PROJECT SCHEDULE

PHASE 2
DESIGN AND CONSTRUCTION

NOTES

- Begins with regulatory approval (see comments on Phase 1 schedule)
- Entails right-of-way acquisition, survey, design, clearing, and construction
- Based on Phase 1 schedule, the earliest in-service date would be late 1995
- Actual in-servic will be determined It depends on a number of factors such as; actual load growth experienced, duration and results of public consultation program, etc